HIGH-RESOLUTION ALBEDO AND RELIEF OF THE LUNAR SURFACE WITH THE IMPROVED PHOTOCLINOMETRY METHOD FOR THE TOPOGRAPHY RECONSTRUCTION FROM A SET OF IMAGES. N. V. Bondarenko, I. A. Dulova and Yu. V. Kornienko, Institute of Radiophysics and Electronics, NAS of Ukraine, 12 Ak.Proskury, Kharkov, 61085, Ukraine (nbondar@ucsc.edu).

Introduction: High-resolution data about the surface of the Moon are routinely obtained in a form of orbital images of the surface illuminated by the Sun. Interpretation of these data often requires knowledge of surface topography; therefore, reconstruction of topography from images is essential. The photoclinometric procedure of recalculation of images into topography is based on a priori known dependence of the surface facet brightness on its orientation. This approach has initially been proposed by Van Diggelen [1]. Unfortunately, it solves a mathematically incorrectly posed problem (see [2]). Attempts to apply such an approach faced different kinds of difficulties and required specific processing algorithms for particular initial sets of images (see, for example, [3]).

In the present work we demonstrate the use of the improved photoclinometry method [2] to disentangle small-scale albedo variations and topographic details of lunar surface.

The improved photoclinometry method: The method of improved photoclinometry is the most mathematically rigorous [2]. It is based on the statistical approach and allows calculation of the most probable surface height variations consistent with the source images. The accuracy of calculated heights depends on the noise level of image data recording. Spatial resolution of the topography obtained is limited by the resolution of source images.

At least two images with different solar azimuths are needed to calculate the heights distribution. Solar azimuths normal to each other are as the most preferable observational conditions. The use of three and more images opens an opportunity to retrieve additionally surface photometric properties, in particular, here we obtain albedo variation.

The improved photoclinometry method includes calculation of topography slope fields from source images. After that [2] the solution of the problem leads to the Poisson equation with von Neumann boundary condition. We applied the finite difference method to solve the Poisson equation and an iteration procedure to calculate the most probable relief along with albedo variations.

Source data: We applied the improved photoclinometry method to a 2.55 × 2.1 km surface area in Mare Imbrium. We processed four images which were portions of LROC [4] images M107005988LE, M183661434LE, M186020337RE, and M188379229LE [5]. These images were taken when solar azimuths (from the North Pole clockwise) A_S were equal to -57.01°, 51.73°, 54.81°, and 17.13° (see Fig. 1), respectively. Differences between solar azimuths for two pairs of images are 95.28° and 92.2° and are consistent with optimal observational conditions for the purposes of relief reconstruction.

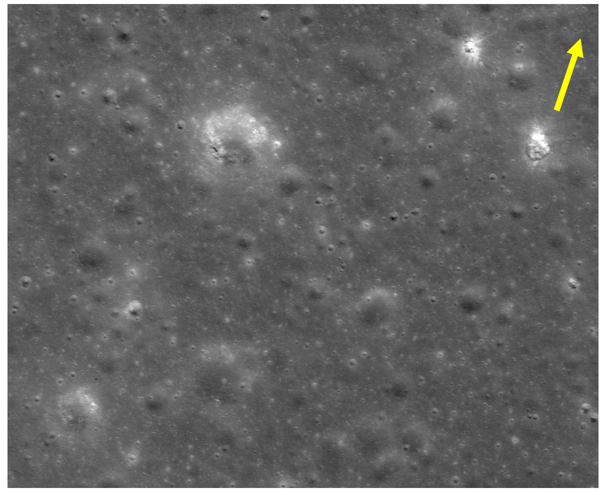

Fig. 1. Lunar surface area under study (2.55 × 2.1 km, center coordinates: 32.56ºN, 340.17ºE): the portion of LROC NA image M186020337RE, A_S = 17.13° (marked with yellow arrow), θ = 32.49 °, SNR = 48.

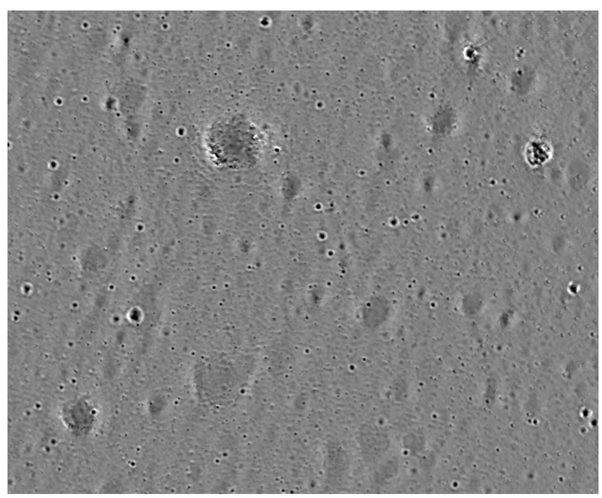

Fig. 2. Calculated relief. Heights vary from -2.9 m to 3.23 m. Darker shades correspond to lower heights.

Illumination incidence angles θ of source images vary between 32° and 46°; the images spatial resolution is in 0.75-1.63 m/pixel range; their signal-to-noise-ratio

SNR varies between 37 and 64. Images were transformed to the resolution of 1.5 m/pixel and coregistered with each other.

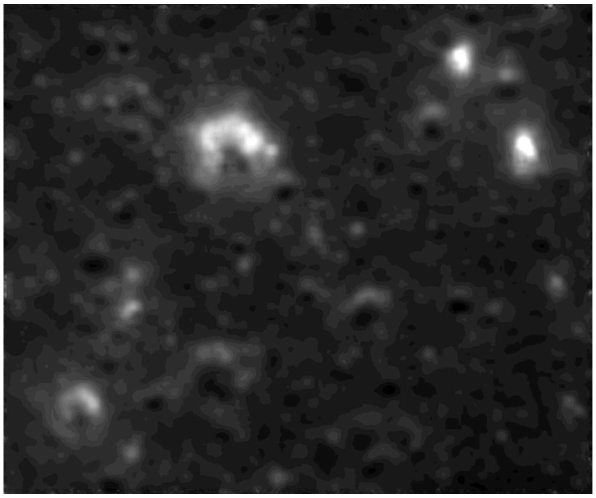

Fig. 3. Albedo distribution. Albedo varies from 0.033 to 0.068. Darker shades correspond to lower albedo.

To calculate surface heights gradient we assumed Lambert's law as an a priori known photometric function of the surface. Initial surface albedo was considered to be constant over the surface and equal to 0.042. This value was calculated as an average of reflectance in the source images taking into account corresponding illumination incidence angle. Albedo / heights variations were corrected during subsequent iteration procedure. To regularize this procedure we impose smoothing albedo variations with 35 m window.

The reconstruction procedure required six iterations of albedo / heights calculation. Heights calculation themselves by the finite difference method involved ~ 2400 iterations.

Results: The resulting topography of the area under study calculated based on four source images is shown in Fig. 2. Heights in the area vary within 6.13 m, from -2.9 to 3.23 m, with standard deviation of 0.15 m.

Number of craters in this area exhibiting circular elevated rims seems to be rather young and fresh. Their diameters vary from 12 to 120 m, they overlap older surface with shallow features, mainly, degraded craters.

The resulted albedo distribution in the area under study calculated according to the procedure discussed above is shown in Fig. 3. Albedo varies from 0.033 to 0.068 with average value of 0.039 and standard deviation equal to 0.0017.

The highest albedo is observed in several craters and appears to indicate immature material. In the relief map (Fig. 2) these craters exhibit distinct structures with sharp rims. Higher albedo values are also associated with their proximal ejecta deposits. Gentle slopes of shallow, heavily degraded craters also have somewhat higher albedo in comparison to their flows and surroundings. This may indicate that these slopes are still in the maturation process.

Conclusions: The improved photoclinometry method for relief reconstruction from images allows simultaneous calculation of the most probable surface topography along with surface photometric properties consistent with the source images. Obtained albedo variations are useful for detailed studies of maturation processes on the lunar surface.

References: [1] Van Diggelen J. (1951) *Neth. Astron. Inst. Bull., 11*, 283-289. [2] Dulova I. A. et al. (2008) *Telecom. Rad. Eng., 67*, 1605-1620. [3] Lohse V. et al. (2006) *PSS*, *54*, 661-674. [4] Robinson M. S et al. (2010) *Space Sci. Rev., 150*, 81-124. [5] http://wms.lroc.asu.edu.